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translator to RWS Group Ltd, of Europa House, Marsham Way, Gerrards Cross, Buckinghamshire, England, do solemnly and sincerely declare that I am conversant with the English and German languages and am a competent translator thereof, and that to the best of my knowledge and belief the following is a true and correct translation of the PCT Application filed under No. PCT/EP2003/011677.

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For and on behalf of RWS Group Ltd

Description
Refractive projection objective for immersion lithography

5   [0001] The   invention   relates   to   a   refractive
projection objective for imaging a pattern, arranged in
an object plane of the projection objective, into an
image plane of the projection objective, with the aid
of an immersion medium that is arranged between a last
10   optical element of the projection objective and the
image plane.

[0002] Photolithographic projection objectives have
been   in   use   for   several   decades   for   producing
15   semiconductor components and other finely structured
structural   elements.   They   serve   the   purpose   of
projecting patterns of photomasks or reticles, which
are also denoted below as masks or reticles, onto an
object coated with a photosensitive layer with very
20   high resolution on a reducing scale.

[0003]   Three developments running in parallel chiefly
contribute to the production of ever finer structures
of the order of magnitude of 100 nm or below. Firstly,
25   an attempt is being made to increase the image-side
numerical aperture (NA) of the projection objectives
beyond the currently customary values into the region
of NA=0.8 or above. Secondly, ever shorter wavelengths
of   ultraviolet   light   are   being   used,   preferably
30   wavelengths of less than 260 nm, for example 248 nm,
193 nm, 157 nm or below. Finally, still other measures
are being used to increase resolution, for example
phase-shifting masks and/or oblique illumination.

35   [0004]   In addition, there are already approaches to
improving the achievable resolution by introducing an
immersion medium of high refractive index into the
space between the last optical element of the
projection objective and the substrate. This technique

is denoted here as immersion lithography. The projection objectives suitable for this purpose are denoted as immersion objectives or immersion systems. Introducing the immersion medium yields an effective wavelength of $\lambda_{eff} = \lambda_0/n$, λ_0 being the vacuum operating wavelength and n the refractive index of the immersion medium. This yields a resolution of $R = k_1 (\lambda_{eff}/NA_0)$ and a depth of focus (DOF) of $DOF = \pm k_2 (\lambda_{eff}/NA_0^2)$, $NA_0 = \sin \Theta_0$ being the "dry" numerical aperture, and Θ_0 being half the aperture angle of the objective. The empirical constants k_1 and k_2 depend on the process.

[0005] The theoretical advantages of immersion lithography reside in the reduction of the effective operating wavelength and the resolution improved thereby. This can be achieved in conjunction with an unchanged vacuum wavelength, and so established techniques for producing light, for selecting optical materials, for coating technology etc. can be adopted largely without change for the appropriate wavelength. However, measures are required for providing projection objectives with very high numerical apertures in the region of NA = 1 or above. Furthermore, suitable immersion media must be available.

[0006] Ultrapure water with $n_1 \approx 1.43$ emerges as a suitable immersion medium for 193 nm.

[0007] The article entitled "Immersion Lithography at 157 nm" by M. Switkes and M. Rothschild, J. Vac. Sci. Technol. Vol. 19 (6), Nov./Dec. 2001, pages 1 ff. presents immersion fluids based on perfluoropolyethers (PFPE) which are sufficiently transparent for a working wavelength of 157 nm and are compatible with some photoresist materials currently being used in microlithography. One tested immersion fluid has a refractive index of $n_1 = 1.37$ at 157 nm. The publication also describes a lens-free optical system, operating with calcium fluoride elements and silicon

mirrors, for immersion interference lithography, which is intended to permit the imaging of 60 nm structures and below in conjunction with a numerical aperture of NA = 0.86. The optical system may not be suitable for
5   use in the series production of semiconductors or the like.

[0008] Patent specifications US 4,480,910 and US 5,610,683 (corresponding to EP 0 605 103) describe
10   projection exposure machines, provided for immersion lithography, having devices for introducing immersion fluid between the projection objective and the substrate. No design is specified for the optical projection system.
15

[0009] It is the object of the invention to provide a refractive projection objective that is suitable for immersion lithography has a compact overall size and can be produced with acceptable use of materials.
20

[0010] This object is achieved by means of a projection objective having the features of claim 1. Advantageous developments are specified in the dependent claims. The wording of all the claims is
25   incorporated in the description by reference.

[0011] In accordance with one aspect of the invention, a refractive projection objective for imaging a pattern, arranged in an object plane of the projection
30   objective, into the image plane of the projection objective, with the aid of an immersion medium that is arranged between a last optical element of the projection objective and the image plane has
a first lens group following the image plane of
35   negative refractive power;
a second lens group following thereupon and of positive refractive power;
a third lens group following thereupon and of negative refractive power;

a fourth lens group following thereupon and of positive refractive power;

a fifth lens group following thereupon and of positive refractive power; and

5   a system diaphragm that is arranged in a transition region from the fourth lens group to the fifth lens group,

wherein the fourth lens group has an entrance surface that lies in the vicinity of a point of inflection of a

10 marginal ray height between the third lens group and the fourth lens group, and no negative lens of substantial refractive power is arranged between the entrance surface and the system diaphragm.

15 [0012] A "negative lens of substantial refractive power" in the meaning of the invention is a lens with a substantially diverging effect for the optical design. This includes, in particular, negative lenses of a refractive power ϕ for which it holds that: $|\phi| > 0.12\text{m}^{-1}$

20 (dpt, diopters).

[0013] A marginal ray height is the perpendicular distance of a marginal ray from the optical axis, a marginal ray leading from the middle of the object

25 field to the diaphragm edge of the system diaphragm determining the numerical aperture used.

[0014] It is preferred to provide no negative lens at all between the entrance surface of the fourth lens

30 group and the system diaphragm such that seated in this region are only positive lenses that counteract an excessively strong enlargement of the beam diameter in the divergent beam path downstream of the entrance surface.

35

[0015] If, in accordance with this aspect of the invention, negative lenses of appreciable refractive power are dispensed with in the region of relatively large beam diameters, it is possible thereby to

restrict the maximum diameter of the lenses in this region to a feasible extent. "Relatively high beam diameters" within the meaning of this application are present, in particular whenever the marginal ray height at a lens is at least as large as half the marginal ray height at the system diaphragm. The invention takes account of the fact that although the divergent effect of a negative lens can be desirable on the grounds of correction, any divergent effect downstream of the negative lens leads to potentially larger lens diameters than would be necessary in the absence of an active lens. In addition, the rays of the beam must be recombined in the direction of the downstream image plane, something which requires positive refractive power. The positive lenses required therefor can be of more moderate design overall when there is not also a need to compensate the divergent effect of negative lenses when bringing the rays together. In addition, the number of lenses can be restricted. The invention thus enables compact projection objectives with a minimal lens mass.

[0016] In some embodiments, no negative lens is arranged between the system diaphragm and the image plane. Consequently, this region can be constructed exclusively with positive lenses that can, if appropriate, be supplemented by an approximately or completely plane-parallel plate.

[0017] The inventive refractive power distribution over the individual lens groups produces a projection objective having two bellies and a waist therebetween, the result being a good correction of the field curvature. It is provided here in the case of preferred embodiments to minimize the number of the changes required for optical correction between lenses of negative and positive refractive power. In one embodiment, a waist of minimal beam diameter exists in the region of the third lens group. There is a lens

pair having lenses immediately following one another and for which $\phi_i * \phi_{i+1} < 0$ between this waist and the image plane at only one location, ϕ_i and ϕ_{i+1} being the refractive powers of the lenses of the lens pair, and,

5    $|\phi| > 0.12m^{-1}$. It is advantageous when lens pairs having such a change between positive and substantially negative refractive power (or vice versa) occur between the object plane and the image plane at only three locations. It is possible thereby to promote the low

10   mass design of such projection objectives.

[0018] It is known that the correction of chromatic aberrations without the use of a second material stimulates additional geometric conditions that must be

15   fulfilled by the beams in the various objective parts. A second optical material can be used in order to circumvent these additional conditions. However, in the wavelength region of deep ultraviolet (DUV) which are provided to the preferred embodiments of the invention,

20   only a few transparent optical materials with sufficiently low absorption are available. For applications at 193 nm, use is made chiefly of synthetic silica glass (SiO_2) as principal material and, as second type of material, fluoride crystal

25   materials such as calcium fluoride (CaF_2) or barium fluoride (BaF_2). As a rule, at 157 nm calcium fluoride is used as principal material and barium fluoride as second material. The targeted use of calcium fluoride at 193 nm can also contribute to securing a longer

30   service life of the objective, since the changes in density observed in synthetic quartz glass do not occur in calcium fluoride given high radiation densities. The fluoride crystal materials that can be used in addition to synthetic quartz glass have substantial

35   disadvantages, however. On the one hand, they are available only to a restricted extent and so the procurement costs are high. In addition, some physical and chemical properties render it difficult to fabricate the optics. Consequently, aspheric surfaces

are used to support the image correction in some
embodiments.

[0019] In one embodiment, the first lens group
includes at least one aspheric surface, at least two
aspheric surfaces preferably being provided in the
first lens group. An arrangement of aspheres in a
region that is near the field and in which the
principal ray height is substantially greater than the
marginal ray height can be used for an effective
distortion correction. The first lens group preferably
includes two lenses with in each case one aspheric
surface. The distribution of aspheres over a number of
lenses simplifies the production, since it is possible
to avoid large surface deformations.

[0020] It has proved to be advantageous when there is
arranged in a first lens region, which is near the
field, in which the principal ray height is large as
against the marginal ray height, at least one aspheric
surface that has a curvature which has at most one
point of inflection in an optically useful range. Two
such surfaces can be provided, for example. More than
three surfaces with one or more points of inflection
should be avoided. Aspheric surfaces that have no, or
at most one, point of inflection of the curvature in
the optically useful range can be effectively mastered
in terms of production engineering and can be produced
with slight surface roughnesses.

[0021] At least one aspheric surface should preferably
occur in the first lens region. It is advantageous,
furthermore, when all the aspheres of the first lens
region fulfill the condition $|\Sigma C1_i| * 10^6 > 0.22$, $C1_i$
being the coefficient of the term h^4 of the aspheric
surface representation of the ith surface. The
parameter $C1_i$ thereby represents the principal
components for deformations of aspheres.

[0022] It is provided in some embodiments that aspheric surfaces with an optically useful diameter of more than 20% of the overall length (object plane/image plane distance) of the projection objective are concave. In the case of some embodiments, this holds for all of the aspheric surfaces. If this condition is observed, the asphere can be tested with sufficient accuracy at an acceptable outlay.

[0023] It has proved to be advantageous with regard to distortion correction when there are arranged in a second lens region, which extends between the object plane and a region in which the principal ray height corresponds substantially to the marginal ray height, at least two aspheric surfaces whose aspheric contributions to distortion are of opposite sides. This contribution can be determined in accordance with $(8 * C1 + k * c^3)(n - n')y\, y_P^3$, C1 being the asphere coefficient, k the conic constant of the asphere, c the curvature, n and n' the indices of refraction upstream and downstream of the surface, y the paraxial marginal ray height at the surface and y_P the paraxial principal ray height at the surface.

[0024] In some embodiments, an advantageous decoupling of optical means for the purpose of providing object-side telecentrism, and of correcting distortions can be achieved by virtue of the fact that the condition $0.9 * PSA31 < PSA3 < 1.1 * PSA31$ is fulfilled for the spherical pupil aberration PSA. Here, PSA31 is the sum of the aberration coefficients of the spherical pupil aberration of all the surfaces inside the first lens region, while PSA3 is the sum of the aberration coefficients are the spherical pupil aberration of all the surfaces of the system. By observing this condition, it is possible to concentrate the pupil aberrations chiefly in the first lens region near the object plane. This is advantageous for decoupling

between influencing telecentrism and influencing
distortion.

[0025] Advantageous embodiments of inventive
projection objectives have an object/image spacing L,
and a focal length f' and use an immersion medium with
a refractive index n_I, the following condition being
fulfilled: $L/f' * n_I > 2.5$. Compact systems with short
focal lengths are possible when this condition is
observed.

[0026] The system diaphragm can be a planar system
diaphragm in the case of which the diaphragm edge
remains independent of the diaphragm diameter set in a
plane perpendicular to the optical axis. In systems
having diaphragm errors, it can be advantageous when
the system diaphragm has a diaphragm edge that
determines the diaphragm diameter and whose axial
position with reference to the optical axis of the
projection objective can be varied as a function of the
diaphragm diameter. This permits optimum adaptation of
the effective diaphragm position to the beam path as a
function of the diaphragm diameter. The system
diaphragm can be designed, for example, as a spherical
diaphragm in which the diaphragm edge can be moved
along a spherical surface during adjustment of the
diaphragm diameter. It is also possible to design the
system diaphragm as a conical diaphragm in which the
diaphragm edge can be moved on a lateral surface of the
cone during adjustment of the diaphragm diameter. This
can be achieved, for example, by means of an axially
displaceable planar diaphragm.

[0027] The invention enables the design of projection
objectives whose image-side numerical aperture is NA ≥
0.9, NA > 0.98, in particular NA = 1.0, NA = 1.1 or
above, also being possible for some embodiments. The
projection objectives can be adapted to an immersion
fluid that has a refractive index of $n_1 > 1.3$ at the

operating wavelength. As a result, the effective
operating wavelength can be reduced by approximately
30% or more by comparison with systems without
immersion.

5

[0028] Projection systems according to the invention
can be provided for a wide range of suitable working
distances. In this case, the object-side working
distance or the working distance in the object space is
10   the (smallest) axial distance between the object plane
and the entrance surface of the objective, while the
image-side working distance or the working distance in
the image space is the (smallest) axial distance
between the exit surface of the objective and the image
15   plane. The working distance in the image space, which
is filled with gas in the event of use as a dry system,
is filled with an immersion medium during operation in
the case of immersion systems.

20   [0029] In the case of immersion systems, special
criteria are to be considered when fixing the working
distance in the image space. A large working distance
on the one hand effects both heavier radiation losses
because of the usually lower transmission of immersion
25   liquids (by comparison with gases), and a higher
contribution to aberration from the surfaces bearing
against the image plane, specifically for spherical
aberration. On the other hand, the image-side working
distance should be large enough to permit a laminar
30   flow of an immersion fluid. If appropriate, there
should also be room for measuring instruments and
sensors. In embodiments most preferred, the image-side
working distance is between approximately 1 mm and
approximately 15 mm, in particular between
35   approximately 1.5 mm and approximately 10 mm. Values
lying between approximately 5 mm, on the one hand, and
approximately 25% to 50% of the object field diameter,
on the other hand, have proved to be advantageous for
the object-side working distance. Although it is true

that values below 5 mm are likewise possible, the requirements placed on surface quality and material quality of the first lens elements, in particular with regard to striations, become more demanding.

[0030] Preferred embodiments are designed as reduction objectives. The magnitude $|\beta|$ of the magnification ratio is preferably in the range from 1/5 to 1/3, in particular between 1/4.5 and 1/3.5, such that, in particular, reductions of 5:1 and 4:1 are possible.

[0031] In a particular embodiment, there is provided in a transition region from the third lens group to the fourth lens group, that is to say in a region of substantially rising beam diameter and divergent radiation, at least one lens doublet that comprises a negative lens and a positive lens following directly in the transmission direction, the negative lens having an image-side concave surface, and the subsequent positive lens having an object-side concave surface. A biconvex air lens is thereby produced between the lenses of the doublet. In particular, the positive lens is a positive meniscus lens concave relative to the object plane and has an entrance-end lens radius R1 and an exit-end lens radius R2, the following condition holding: $(R1 + R2)/(R1 - R2) < -1.5$. Occurring in the region of the lens doublet, in particular at the concave exit end, curved against the beam path, of the negative lens are high incidence angles of the penetrating radiation that can make a very effective contribution to the correction of the overall system. At least one of the lens surfaces bordering the inner air lens can be aspheric. It is preferred for both boundary surfaces to be aspheric.

[0032] In one development, at least one meniscus lens of positive or weakly negative refractive power that is concave relative to the object plane and fulfills the condition $D_L/D_{min} > 1.3$ is arranged in the fourth lens

group, D_{min} being the smallest light pencil diameter in the fourth lens group and D_L being the maximum light pencil diameter in the meniscus lens. A combination of a weakly negative meniscus lens with a positive lens in the diaphragm region can make an effective contribution to the correction of aperture-dependent aberrations, in particular the spherical aberration.

[0033] In some embodiments, all the lenses of the projection objective consist of the same material. The material used can be, for example, synthetic silica glass for operating wavelengths of 193 nm, and calcium fluoride for operating wavelengths of 157 nm. The use of only one type of material makes the production easier and permits simple adaptation of the objective design to other wavelengths. It is also possible to combine a number of types of material in order, for example, to assist correction of chromatic aberrations. Also possible is the use of other UV-transparent materials such as BaF_2, NaF, LiF, SrF, MgF_2 or the like.

[0034] In some embodiments that are designed predominately from quartz glass lenses, at least two of the lens elements arranged in the immediate vicinity of the image plane consist of a fluoride crystal material of identical crystal orientation. The service life of the projection objectives can be improved thereby. It has proved to be advantageous for correcting the transverse chromatic aberration when at least one positive lens made from a fluoride crystal material is present in the second lens group. The use of a fluoride crystal material as lens material of a positive lens in the fourth lens group can also make an effective contribution to correcting the transverse chromatic aberration. The correction of the transverse chromatic aberration can be improved when a fluoride crystal material is used as lens material in the case of at least one negative lens of the third lens group.

[0035] In addition to emerging from the claims, the foregoing and further features also emerge from the description and the drawings, it being possible for the individual features to be implemented alone or multiply in the form of subcombinations for embodiments of the invention and in other fields, and to constitute advantageous designs which are patentable on their own merit.

Figure 1   is a lens section through a first embodiment of a refractive projection objective which is designed for an operating wavelength of 193 nm;

figure 2   is a lens section through a second embodiment of a projection objective which is designed for an operating wavelength of 193 nm;

figure 3   is a lens section through a third embodiment of a projection objective which is designed for an operating wavelength of 193 nm;

figure 4   is a lens section through a fourth embodiment of a projection objective which is designed for an operating wavelength of 193 nm;

figure 5   is a lens section through a fifth embodiment of a projection objective which is designed for an operating wavelength of 193 nm;

figure 6   is a lens section through a sixth embodiment of a projection objective which is designed for an operating wavelength of 193 nm.

[0036] In the following description of the preferred embodiments, the term "optical axis" denotes a straight line through the centers of curvature of the optical components. Directions and distances are described as on the image side or towards the image, when they are

directed in the direction of the image plane or the substrate which is located there and is to be exposed, and as on the object side or towards the object when they are directed towards the object with reference to the optical axis. In the examples, the object is a mask (reticle) with the pattern of an integrated circuit, but another pattern, for example a grating, can also be involved. In the examples, the image is formed on a wafer serving as substrate and coated with a photoresist layer, but other substrates are also possible, for example elements for liquid crystal displays or substrates for optical gratings. The specified focal lengths are focal lengths with reference to air.

[0037] A typical design of an embodiment of an inventive, purely refractive reduction objective 1 is shown with the aid of figure 1. Given virtually homogenous immersion, it serves the purpose of imaging a pattern, arranged in an object plane 2, of a reticle or the like into an image plane 3 to a reduced scale, for example to the scale of 5:1 (magnification ratio $\beta = 0.2$). This is a rotationally symmetrical single-waist system or two-belly system with five consecutive lens groups that are arranged along the optical axis 4, which is perpendicular to the object plane and image plane. The first lens group LG1 directly following the image plane 2 has a negative refractive power. A second lens group LG2 following directly thereupon has a positive refractive power. A third lens group LG3 following directly thereupon has a negative refractive power. A fourth lens group following directly thereupon has a positive refractive power. A fifth lens group LG5 following directly thereupon has a positive refractive power. The image plane directly follows the fifth lens group such that the projection objective has no further lens or lens group apart from the first to fifth lens group. This distribution of refractive power provides a two-belly system that has an object-side first belly 6,

an image-side belly 8 and a waist 7 lying therebetween in which lies a waist X with a minimum beam diameter. In a transition region from the fourth lens group to the fifth lens group the system diaphragm 5 lies in the
5   region of a relatively large beam diameter.

[0038] The projection possible with the aid of the projection objective can be characterized by the course of its principal rays and marginal rays. Denoted as
10   principal ray A is a ray that runs from an outer marginal point of the object field parallel or at an acute angle to the optical axis and cuts the optical axis 4 in the region of the system diaphragm 5. A marginal ray B leads from the middle of the object
15   field, that is to say from an axial field point, to the diaphragm edge of an aperture stop that is normally seated at the location of the system diaphragm 5 or in its immediate vicinity. A ray C that leads from an outer field point to the opposite edge of the aperture
20   stop is denoted here as coma ray. The perpendicular distance of these rays from the optical axis yields the corresponding ray heights h_A, h_B and h_C.

[0039] With reference to these beam paths, the fourth
25   lens group LG4 has an entrance surface E that lies in the vicinity of a point of inflection of a marginal ray height in the third lens group LG3 and the fourth lens group LG4.

30   [0040] A first lens region LB1 begins at the object plane 2 and ends in the plane in which the marginal ray B and the coma ray C intersect such that the condition $|h_B/h_C| < 1$ is fulfilled in the first lens region LB1. The principal ray height is large in this lens region
35   LB1 by comparison with the marginal ray height. Lens surfaces arranged here are denoted as near field. A second lens region LB2 extends from the object plane 2 as far as into the region in which the principal ray height and the marginal ray height are approximately

equal in order of magnitude, in which case $|h_B/h_A| < 1.2$ holds, in particular. For typical variants of inventive projection systems, the length of the second lens region LB2 is greater than a quarter and smaller than half the distance L between the object plane 2 and image plane 3. This object-image distance is also denoted as the overall length of the projection objective.

[0041] For typical embodiments of inventive projection objectives, the first lens group LG1 has at least two negative lenses, the second lens group LG2 at least three positive lenses, the third lens group LG3 at least two negative lenses, the fourth lens group LG4 at least two positive lenses and the fifth lens group LG5 at least three positive lenses.

[0042] The first lens group LG1, which follows the object plane 2, is substantially responsible for widening the light bundle into the first belly 6. It has a thin negative lens 11 with an aspheric entrance surface, a further thin negative lens 12, following thereupon, with an aspheric entrance surface and a thick double spherical meniscus lens 13, following thereupon, with an object-side concave surface and of weak refractive power. The aspheres, arranged near the field, on the entrance surfaces of the lenses 11, 12 nearest the object contribute effectively to the good correction of the distortion and the astigmatism, above all the correction of telecentrism. The distribution of the asphericity over two lens surfaces of different lenses can simplify the production of the lenses.

[0043] The second lens group LG2 comprises four positive lenses 14, 15, 16, 17, specifically an entrance-end meniscus lens 14 with an aspheric entrance surface and an object-end concave surface, made by a biconvex lens 15, a thick positive meniscus lens 16 with an aspheric, concave exit surface and a further

positive meniscus with the same sense of curvature of its spherical lens surfaces. This design, in the case of which the curvatures of the meniscus surfaces on the object side and image side of the biconvex lens 15 run in opposite senses and with mutually averted concave surfaces, ensures low superficial loadings for the meniscuses and the positive lens, and thus slight aberrations. A biconcave air lens between the biconvex positive lens 14 and the downstream meniscus 16 provides a strong astigmatic undercorrection, and therefore exerts an advantageous influence on the compensation of the contributions of astigmatism in the front part of the system upstream of the waist 7.

[0044] The third lens group 3 comprises three negative lenses 18, 19, 20. A biconcave lens 18 with spherical lens surfaces is arranged in this case at a distance upstream of the waist X of least beam diameter. Following at a distance downstream of the waist is a negative meniscus lens 19 with an object-side concave spherical entrance surface and an aspheric exit surface. Following this is a biconcave negative lens 20 with a spherical entrance surface and aspheric exit surface. The aspheric surfaces on the exit sides of the lenses 19, 20 make an extensive contribution to correcting the coma and the astigmatism.

[0045] The beam has maximum divergence downstream of the exit-end negative lens 20 of the third lens group LG3, very large incidence angles of the penetrating radiation that produce a strong corrective effect occurring on the aspheric exit side of the lens 20.

[0046] The fourth lens group LG4 comprises at its entrance end two positive meniscus lenses 21, 22 that are concave in relation to the object plane and which are followed by a biconvex positive lens 23 immediately upstream of the system diaphragm 5. Here, only the entrance surface of the front lens 21 is aspheric, all

the other surfaces of the fourth lens group being spherical. Whereas the third lens group LG3 comprises only negative lenses and introduces a strong beam divergence, the subsequent fourth lens group LG4
5   comprises only positive lenses and exerts a strongly converging influence such that the divergent angle increases rapidly toward the system diaphragm 5. The transmission between negative and downstream positive refractive power produces between the third and fourth
10   lens groups a point of inflection of the marginal ray height in the vicinity of which the entrance surface E of the fourth lens group lies. It is a particular feature of this design that there is no lens of negative refractive power arranged between this
15   entrance surface E and the system diaphragm.

[0047] The fifth lens group LG5 lying downstream of the system diaphragm 5, is substantially responsible for the production of the high numerical aperture.
20   Exclusively collective lenses are provided for this purpose, specifically a positive meniscus lens, seated immediately downstream of the system diaphragm, with a spherical entrance surface and an aspheric exit surface concave on the image side, a virtually planoconvex
25   positive lens 26 with a virtually planar entrance surface and a convex exit surface, a positive meniscus lens 27, following thereupon, with a spherical entrance surface and an image-side concave, aspheric exit surface, a further positive meniscus lens 28 with a
30   spherical entrance surface and an image-side concave, aspheric exit surface, and a terminating planoconvex lens 29 with a spherical entrance surface and a planar exit surface. The positive lenses exert a spherically strongly undercorrecting effect and, with respect to
35   the coma, an overcorrecting effect. With this design, the correction of the spherical aberration and of the coma is largely borne by the weakly negative/positive doublet in the transition between the third and fourth lens groups, and by the aspheric surfaces, near the

diaphragm, of the fourth and fifth lens groups. As a result, the fourth lens group LG4 and the fifth lens group LG5 are responsible in combination for achieving a good correction state of the spherical aberration and

5   of coma.

[0048] The system has an object-side working distance (object back focal distance) of 32 mm and an image-side working distance of 6 mm that can be filled up by an

10 immersion liquid 10. This system is designed such that deionized water (refractive index n $\approx$ 1.47) or another suitable transparent liquid with a comparable refractive index can be used as immersion liquid at 193 nm.

15

[0049] The specification of the design is summarized in a known way in tabular form in table 1. Here, column 1 specifies the number of a refracting surface, or one distinguished in another way, column 2 specifies the

20 radius r of the surface (in mm), column 4 specifies the distance d, denoted as thickness, of the surface from the following surface (in mm) and column 5 specifies the material of the optical components. Column 6 shows the refractive index of the material and the useful,

25 free radii or half the free diameter of the lenses (in mm) are specified in column 7. The aspheric surfaces are denoted by "AS" in column 3.

[0050] In the case of the embodiment, ten of the

30 surfaces, specifically the surfaces 2, 4, 8, 13, 19, 21, 22, 31, 35 and 37 are aspheric. Table 2 specifies the corresponding aspheric data, the aspheric surfaces being calculated using the following rule:

35 $p(h) = [((1/r)h^2)/(1+SQRT(1-(1+K)(1/r)^2h^2))]+C1*h^4+C2*h^6+...$

[0051] Here, the reciprocal $(1/r)$ of the radius specifies the surface curvature, and h the distance of a surface point from the optical axis (that is to say

the ray height). Consequently, p(h) gives the so-called sagitta, that is to say the distance of the surface point from the surface apex in the z direction, that is to say in the direction of the optical axis. The constants K, C1, C2, ... are reproduced in Table 2.

[0052] The optical system 1, which can be reproduced with the aid of these data, is designed for an operating wavelength of approximately 193 nm, for which the synthetic quartz glass used for all the lenses has a refractive index n = 1.5608. The image-side numerical aperture is 1.0. The object-side and image-side telecentric system is adapted to a refractive index of the immersion medium 10 of n_I = 1.47. The objective has an overall length L (distance between image plane and object plane) of approximately 1037 mm. A photoconductance (product of numerical aperture and image size) of approximately 22 mm is achieved for an image size of approximately 22 mm.

[0053] A few particular features of the projection objective are explained below. The projection object has only five negative lenses, which are concentrated on the one hand near the object at the input (lenses 11, 12) and on the other hand in the region of the waist 7 (lenses 18, 19 and 20). Consequently, it is only at three sites in the system that there is a transition between lenses of different sign of refractive power, specifically a negative/positive transition within the first lens group LG1 between the lenses 12 and 13, a positive/negative transition between the lens groups LG2 and LG3 or the lenses 17 and 18, and a negative/positive transition between the lens groups LG3 and LG4. Only positive lenses are located up to the object plane downstream of the last transition, which takes place in the region of the entrance surface E of the fourth lens group and defines a point of inflection in the profile of the marginal ray height downstream of the location X of narrowest

constriction. By dispensing with negative lenses in this region, and owing to the possibility thereby of avoiding diverging refractive powers, it is possible for the lens diameters in the second belly 8 to be kept relatively slight, as a result of which the design can be of low mass overall. At the same time, the number of lenses can be kept low; only ten lenses occur between the location X of narrowest constriction and the image plane, and there are only 18 lenses in the entire system. This likewise promotes a compact design of low mass.

[0054] With one exception (convex exit side of the smallest lens 19 in the waist 7), all the aspheres are located on concave lens surfaces. This facilitates the testing of the aspheres when producing the lenses because, by contrast with the testing of convex surfaces, it is possible to use relatively compact test optics for testing concave surfaces. It may be seen from the asphere data in table 2 that no strong deformations occur with the aspheres and that the aspheric surfaces have either no, or at most one, point of inflection in their curvature. This facilitates the fabrication of the aspheres, thus enabling, in particular, aspheric surfaces with low surface roughnesses.

[0055] The biconcave negative lens 20 at the exit of the third lens group LG3, and the positive meniscus lens 21 concave on the image side, at the input of the fourth lens group LG4, form a negative/positive lens doublet that makes a substantial contribution to the total correction of the system. This can be influenced by the design of the mutually facing aspheric surfaces of this lens doublet, which delimit a biconvex air lens at which high incidence angles of the radiation occur. It is chiefly the spherical aberration of all orders that are corrected thereby. At the same time, other aberrations of higher order such as coma and

astigmatism are also strongly influenced. Because of
the high incidence angles, the image-side surface of
the lens 20 acts in a strongly overcorrecting fashion
on the spherical aberration. By contrast therewith, the
5   shape of the object-side surface of the next lens has
an effect such that the rays with small incidence
angles impinge thereon, and so only small contributions
to the spherical aberration are produced. The soft
deflection of the rays in the lens groups LG4 and LG5
10   does undercorrect the spherical aberration, but not
strongly enough to exceed the overcorrection. A
virtually complete correction is achieved in this way.

[0056]   A variant of the embodiment shown in figure 1
15   is explained with the aid of figure 2. Here, the
features of the basic design are denoted by the same
reference symbols as in figure 1. The system has an
image-side   numerical   aperture   NA = 1.1.   The
specification of this design is to be found in tables 3
20   and 4.

[0057]   The design of the first lens group LG1 and of
the second lens group LG2 corresponds substantially to
the first embodiment in figure 1. By contrast
25   therewith, the thick positive meniscus lens 16 there is
split into two thinner positive meniscus lenses 116,
116', as a result of which it is possible to reduce the
superficial loading of the optical surfaces. In the
case of the lenses of the third lens group LG3, the
30   negative meniscus lens 19 has substantially been
replaced by a biconcave negative lens 119 that is
seated closer to the location of X of smallest
constriction.

35   [0058]   As in the case of the embodiment in accordance
with figure 1, the fourth lens group is introduced by
an object-side concave positive meniscus 121 with an
aspheric entrance surface. Following thereafter in the
fourth lens group are a biconvex positive lens 122 with

an aspheric entrance surface, a double spherical, biconvex positive lens 123 and a positive meniscus 124, arranged immediately upstream of the system diaphragm 5, with a weakly positive refractive power. The positive meniscus lens 124 is seated in the weakly divergent beam path upstream of the diaphragm, and has an object-side concave surface at which relatively high incidence angles that support the correction occur.

[0059] The fifth lens group LG5 comprises five positive lenses 125, 126, 127, 128 and 129. An entrance-side biconvex lens 125 with an aspheric exit surface projects into the region of the system diaphragm 5. Following thereupon are three positive meniscus lenses 126, 127 and 128 concave relative to the image plane, the exit surfaces of the two last-named lenses 127, 128 being aspheric. A planoconvex lens 129 with a spherical entrance surface and planar exit surface terminates the system on the image side.

[0060] An aperture stop of adjustable diaphragm diameter in this system can be designed as a spherical diaphragm in order to avoid contact with the entrance side of the biconvex lens 125 during stopping down. Alternatively, an axially movable, if appropriate planar diaphragm can be used.

[0061] As with the embodiment in accordance with figure 1, only five negative lenses are provided, these being concentrated into two groups (input group 111, 112 and lens group LG3). Consequently, it is only at three sites that a change takes place between different signs of the refractive power. Only positive lenses lie between the entrance surface E of the fourth lens group and the image plane, and so the rays are recombined very efficiently downstream of the waist in the direction of the image plane, and the lens diameters can be kept moderate. Despite the very high numerical aperture of NA = 1.1, the number of the lenses is

relatively low at 20, a compact design with optimized mass thereby being achieved.

[0062]   Shown in figure 3 is a third embodiment of an inventive projection objective, which constitutes a variant of the first or second embodiments. In this case, the features of the basic design are denoted by the same reference symbols as in figures 1 and 2. The system has an image-side numerical aperture NA = 1.1. The specification of the design is given in tables 5 and 6.

[0063]   The design of the first lens group LG1 and the second lens group LG2 corresponds substantially to the embodiment in accordance with figure 2. Reference is made to the description there. By contrast with the embodiment in accordance with figure 2, the entrance surface of the biconcave meniscus lens 218 is aspheric in the case of the lenses of the third lens group LG3. The subsequent negative lens 219 is fashioned as a meniscus with an object-side concave surface and aspheric exit surface, and is seated, as in the embodiment in figure 1, at a distance downstream of the waist X.

[0064]   The design of the fourth lens group LG4 corresponds with reference to the type and the sequence of the lenses to the design of the first embodiment in accordance with figure 1, and so reference is made to the description there. By contrast to the lens group LG4 there, however, the entrance side of the middle positive lens 222 of this lens group is aspheric.

[0065]   The fifth lens group LG2 comprises five positive lenses 225, 226, 227, 228, 229. The entrance side, thick biconvex lens 225 with an aspheric exit surface projects into the region of the system diaphragm 5 such that a spherical diaphragm or an axially displaceable aperture stop, for example, is

provided here. Following downstream is the double spherical biconvex positive lens 226. This is followed by two positive meniscus lenses 227 and 228 that are concave relative to the image plane and whose entrance
5   surfaces are spherical and whose exit surfaces are aspheric. A planoconvex lens 229 with an aspheric entrance surface and planar exit surface terminates the system on the image side.

10 [0066] A particular feature of this system by comparison to the other systems consists in that the diameter of the object-side first belly is much smaller than the diameter of the image-side second belly 8. The result of this in the region of the entrance surface E
15 of the fourth lens group is a particularly strong beam divergence with high incidence angles effective in correction, above all at the aspheric exit of the negative lens 220. The ratio between the maximum diameter of the second belly and the maximum diameter
20 of the first belly is closely connected to the color correction of the system. The smaller the diameter of the first belly, the better is the correction of the transverse chromatic aberration. In this embodiment, this ratio is approximately 1.37, a good correction of
25 the chromatic aberration being achieved as a result.

[0067] A fourth embodiment is explained with the aid of figure 4. Here, the features of the basic design are denoted by identical reference symbols as in the case
30 of the previous embodiments. The system has an image-side numerical aperture NA = 1.1. The specification of this design is given in tables 7 and 8.

[0068] The design of the first lens group LG1 and the
35 second lens group LG2 corresponds substantially to that of the third embodiment or the second embodiment, and so reference may be made to the description there. The differences exist chiefly in the design of the output-side lenses 316, 316' and 317 of LG2. Although, as in

the case of the embodiment in accordance with figure 3,
these lenses are designed as positive meniscus lenses
with image-side concave surfaces, the bending differs
from that of the other embodiments. The positive lens
5   316 has a spherical entrance surface and an only weakly
curved, concave exit surface. It is followed by a
strongly curved meniscus 316' of very weak refractive
power and by an aspheric exit side. This is followed
with a slight air separation by the convex, spherical
10 entrance surface, curved in the same sense, of the
meniscus 317, which has a concave, spherical exit
surface.

[0069] Inside the third lens group LG3, the middle
15 negative lens 319 there is formed by a meniscus that is
concave on the image side and has an aspheric exit
surface, and which is seated in the immediate vicinity
of the site X of smallest constriction.

20 [0070] As in the case of the other embodiments, the
transition between the third and fourth lens groups is
formed by a strongly correcting lens doublet 320, 321
with mutually facing, aspheric concave surfaces in the
region of which high incidence angles occur.
25

[0071] Following the positive meniscus 321, which is
convex on the image side, inside the fourth lens group
is a biconvex positive lens 322 with an aspheric
entrance side, a double spherical biconvex positive
30 lens 323 with a virtually planar exit surface, a
meniscus 324, concave relative to the image plane, of
weakly negative refractive power (-0.11 m^{-1}), and a
thin, double spherical positive meniscus 324', with an
object-side concave surface. The mutually facing
35 concave surfaces of the meniscuses 324, 324' enclose a
biconvex air lens in the region of which there lies a
small constriction of the beam path. Spherical
aberration and coma are corrected substantially more
easily as a result, and so the diameter of the second

belly can be reduced.

[0072] With reference to the type of lenses, the design of the fifth group LG5 downstream of the system diaphragm 5 corresponds fundamentally to the embodiment in accordance with figure 2, and so reference is made to the description there.

[0073] In a particular configuration of the lenses in the output region of the first belly and, in particular, the oppositely curved meniscuses 324, 324' of weak refractive power immediately upstream of the system diaphragm provide novel correction means that enable the maximum diameter of the lenses of this system to be substantially reduced by comparison with the previous embodiments. A compact design of low mass is thereby promoted.

[0074] A variant of the second embodiment shown in figure 2 is explained with the aid of figure 5. Here, the features of the basic design are denoted by the same reference symbols as in figure 2, the reference symbols for the lenses being increased by 300 in each case. The type and sequence of the lenses do not differ from the embodiment in accordance with figure 2, and so reference is made to this extent to the description there. The specification of this design is given in tables 9 and 10.

[0075] By contrast with this design in accordance with figure 2, in the projection objective 400 the input-side lenses 411, 412 are of slightly thicker configuration, likewise the middle lens 419 of the third lens group LG3, which is configured here as a negative meniscus with an image-side concave surface.

[0076] A particular feature of this system is a substantially smaller working distance in the object space. This amounts here for an object field diameter

of approximately 112 mm to only 9.14 mm (instead of
32 mm for the second embodiment). (The object field
diameter of the objective can be taken in each case
from the tables as twice the free radius (1/2 diameter)

5   of the surface No. 0). The correcting influence of the
first lens group LG1 on the field curvature is
intensified by the smaller object-side working
distance. This enables a particularly stress-relieved
design of the third lens group LG3 with simultaneous

10   reduction in the aberration contribution. Moreover, the
telecentrism and distortion can be more effectively
corrected. The system in accordance with figure 5 is
generally more stress-relieved and has improved
corrigibility by comparison with the system in

15   accordance with figure 2. It has emerged that values
for the object-side working distance of between
approximately 5 mm and approximately 25% up to
approximately 50% of the object field diameter are
particularly favorable. For values below 5 mm, the

20   requirements placed on the surface quality and the
material quality, in particular with reference to
striations, of the first lens elements rise sharply.
The advantage reduces in the event of relatively large
working distances.

25

[0077] The use of the object back focus distance
(object-side working distance) as correcting means can
be explained in the following fashion: on the one hand,
the reduction in the object back focus distance

30   intensifies the influence of the first lens group of
negative refractive power on the field curvature. This
permits a stress-relieved design of the third lens
group (waist), with simultaneous reduction in its
aberration contributions. On the other hand, the

35   telecentrism and the distortion can be more strongly
influenced and thereby corrected. A certain separation
of telecentrism correction and distortion correction is
possible.

[0078] A short working distance in the object space permits not only the front lenses to come closer to the object, but also the aspheres, which are borne by the latter. This additionally intensifies their correcting action on the field-dependent aberrations.

[0079] The minimum working distance should be set such that the subapertures on the front asphere are sufficiently large that the specification of the surface quality can still be accommodated in the aberration budget.

[0080] Such short object-side working distances can be useful in the case of all high-aperture lithography projection objectives, for example with image-side numerical apertures from approximately NA = 0.8 (dry) up to the immersion objectives, shown in the examples, with NA = 1.1 or greater (currently up to NA = 1.3). This holds, in particular, whenever the object-side working distance lies below 20 mm or even below 10 mm. Restrictions placed on the free design space for reticle handling are usually not so high-ranking as the achievable advantages in optical correction with such high apertures.

[0081] A variant of the first embodiment shown in figure 1 is explained with the aid of figure 6. Here, the features of the basic design are denoted by the same reference symbols as in figure 1. The lenses bear corresponding reference symbols, increased by 500. The specification of this design is given in tables 11 and 12.

[0082] By contrast with the embodiment in accordance with figure 1, the fourth lens 514, following the object plane, is not configured as a positive meniscus, but virtually as a planoconvex lens. The middle lens 519 of the third lens group is seated in the middle between the adjacent negative lenses and is not

configured as a meniscus lens, but as a biconcave lens. All the lens elements downstream of the system diaphragm 5 are fashioned as positive meniscus lenses with an image-side concave surface. The diameters in
5 the second belly thereby become smaller, and at the same time the system diaphragm is provided with a larger movement space. A substantial difference from the embodiment in accordance with figure 1 is the very small working distance in the image space, which
10 amounts here only to 1.73 mm (by contrast with approximately 13 mm in figure 1). Transmission problems in the immersion medium are thereby reduced.

[0083] The invention also relates to a projection
15 exposure machine for microlithography that is distinguished in that it includes a refractive projection objective in accordance with the invention. The projection exposure machine preferably also has devices for introducing and holding an immersion
20 medium, for example a liquid of suitable refractive index, between the last optical surface of the projection objective and the substrate to be exposed. Also comprised is a method for producing semiconductor components and other finely structured components in
25 the case of which an image of a pattern arranged in the object plane of a projection objective is imaged in the region of the image plane, an immersion medium that is arranged between the projection objective and the substrate to be exposed and is transparent to light of
30 the operating wavelength being transirradiated.

Table 1

SURFACE	RADII		THICKNESS	MATERIAL	INDEX	½ DIA.
0	0.000000000		32.000000000	LUFTV193	1.00030168	56.080
1	0.000000000		0.000000000	LUFTV193	1.00030168	64.285
2	-865.050540254	AS	8.000000000	SIO2V	1.56078570	64.285
3	290.818451556		12.977949377	N2VP950	1.00029966	66.587
4	-785.540458496	AS	8.000000000	SIO2V	1.56078570	67.984
5	993.943579336		32.783966724	N2VP950	1.00029966	70.962
6	-111.758943889		84.059022555	SIO2V	1.56078570	72.541
7	-157.792863838		1.000000000	N2VP950	1.00029966	110.623
8	-976.343592324	AS	29.745781546	SIO2V	1.56078570	126.319
9	-302.211713385		1.000000000	N2VP950	1.00029966	128.519
10	861.145865697		39.130890181	SIO2V	1.56078570	135.470
11	-462.739285409		1.000000000	N2VP950	1.00029966	135.872
12	170.741772483		84.048926757	SIO2V	1.56078570	128.315
13	271.206057493	AS	1.000000000	N2VP950	1.00029966	107.756
14	136.915825828		48.838558347	SIO2V	1.56078570	99.678
15	213.245426279		25.207226449	N2VP950	1.00029966	85.576
16	-918.293529854		8.000000000	SIO2V	1.56078570	83.141
17	95.947147465		88.880628458	N2VP950	1.00029966	68.943
18	-114.002344853		8.000000000	SIO2V	1.56078570	68.191
19	-193.441060843	AS	18.779522128	N2VP950	1.00029966	72.266
20	-108.981149024		8.000000000	SIO2V	1.56078570	72.928
21	337.229009012	AS	34.264924267	N2VP950	1.00029966	90.855
22	-378.436104518	AS	41.010541982	SIO2V	1.56078570	99.638
23	-163.510794786		1.000000000	N2VP950	1.00029966	109.697
24	-1048.483558130		48.106157417	SIO2V	1.56078570	131.422
25	-212.098893173		1.000000000	N2VP950	1.00029966	134.785
26	455.564493212		38.863091168	SIO2V	1.56078570	151.792
27	-2411.753669630		9.000000000	N2VP950	1.00029966	151.861
28	0.000000000		0.000000000	N2VP950	1.00029966	151.670
29	0.000000000		1.000000000	N2VP950	1.00029966	151.732
30	396.383711792		20.855290362	SIO2V	1.56078570	154.881
31	692.061959851	AS	53.642541173	N2VP950	1.00029966	154.181
32	-27619.070745400		37.463229296	SIO2V	1.56078570	154.778
33	-416.737141814		1.000000000	N2VP950	1.00029966	154.883
34	208.730269126		50.922368160	SIO2V	1.56078570	136.985
35	1250.936698020	AS	1.000000000	N2VP950	1.00029966	133.556
36	149.168582835		54.192578417	SIO2V	1.56078570	109.143
37	195.589235389	AS	1.000000000	N2VP950	1.00029966	87.757
38	133.474284291		100.901991415	SIO2V	1.56078570	81.472
39	0.000000000		6.000000000	H2OV	1.43636732	19.897
40	0.000000000		-0.000005061		1.00000000	14.020

Table 2

ASPHERIC CONSTANTS

SURFACE NO. 2	
K	0.0000
C1	2.22079559e-007
C2	-2.64018719e-011
C3	2.50852766e-015
C4	-3.25400366e-019
C5	3.53141037e-023
C6	-2.57029540e-027
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 13	
K	0.0000
C1	5.69048541e-009
C2	2.22660165e-013
C3	5.06834768e-019
C4	-5.28569590e-022
C5	-7.86940964e-027
C6	-2.04428899e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 4	
K	0.0000
C1	7.87748495e-009
C2	1.51301853e-011
C3	-1.45712594e-015
C4	1.23713065e-019
C5	-1.06714221e-023
C6	9.37529787e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 19	
K	0.0000
C1	3.73796256e-008
C2	-3.23750168e-012
C3	-2.99948447e-016
C4	-1.26432681e-020
C5	-1.99316836e-024
C6	2.17020495e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 8	
K	0.0000
C1	1.15089618e-009
C2	1.75526288e-013
C3	5.50342306e-018
C4	-5.03060695e-023
C5	-3.74390222e-027
C6	2.35013568e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 21	
K	0.0000
C1	-4.47941204e-008
C2	1.91031010e-012
C3	-6.87449830e-017
C4	3.10021117e-021
C5	-2.27317966e-025
C6	7.02595515e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Table 2 (Continued)

SURFACE NO. 22	
K	0.0000
C1	-2.17284274e-008
C2	2.24196148e-013
C3	-5.21041812e-018
C4	-9.18268284e-023
C5	3.33452899e-027
C6	1.17806194e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 35	
K	0.0000
C1	-4.95304387e-010
C2	3.68346595e-013
C3	-1.14699839e-017
C4	3.56713006e-022
C5	-8.33238537e-027
C6	1.16876976e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 31	
K	0.0000
C1	4.34168273e-010
C2	6.79894644e-014
C3	8.53259806e-019
C4	-3.70631658e-023
C5	9.42929641e-028
C6	-9.21609297e-033
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 37	
K	0.0000
C1	6.27172010e-009
C2	4.74147771e-013
C3	6.99599832e-017
C4	-8.95486009e-022
C5	7.42088130e-026
C6	1.36162977e-029
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Table 3

SURFACE	RADII		THICKNESS	MATERIAL	INDEX	½ DIA.
0	0.000000000		32.000000000	LUFTV193	1.00030168	56.080
1	0.000000000		0.000000000	LUFTV193	1.00030168	65.329
2	-862.369062961	AS	7.338632000	SIO2V	1.56078570	65.329
3	1729.160869900		8.274822683	N2VP950	1.00029966	66.763
4	-447.956682044	AS	7.338632000	SIO2V	1.56078570	67.694
5	395.435201480		39.423033814	N2VP950	1.00029966	71.219
6	-103.758498877		72.684309488	SIO2V	1.56078570	72.711
7	-154.563177595		0.917329000	N2VP950	1.00029966	108.819
8	-780.383884859	AS	32.249416462	SIO2V	1.56078570	125.591
9	-256.700260496		0.917329000	N2VP950	1.00029966	127.994
10	890.876055318		40.079600210	SIO2V	1.56078570	137.132
11	-439.438418565		0.917329000	N2VP950	1.00029966	137.633
12	174.112406867		37.588836160	SIO2V	1.56078570	131.138
13	294.417657706		0.917329000		1.00000000	128.131
14	193.947508268		19.661875223	SIO2V	1.56078570	122.533
15	254.407260784	AS	0.917329000	N2VP950	1.00029966	118.763
16	150.175439934		46.836170975	SIO2V	1.56078570	110.351
17	634.351476536		12.890800996	N2VP950	1.00029966	105.519
18	-6207.994384690		7.338632000	SIO2V	1.56078570	101.889
19	89.325322950		57.391056746	N2VP950	1.00029966	75.356
20	4999.526146000		7.338632000	SIO2V	1.56078570	73.134
21	179.724355387	AS	48.429517423	N2VP950	1.00029966	71.160
22	-99.598077900		7.338632000	SIO2V	1.56078570	71.490
23	303.140682220	AS	29.505975384	N2VP950	1.00029966	91.187
24	-370.484993955	AS	59.205322959	SIO2V	1.56078570	95.002
25	-136.850476930		0.917329000	N2VP950	1.00029966	109.198
26	833.250243086	AS	32.644361706	SIO2V	1.56078570	144.418
27	-773.094655176		0.917329000	N2VP950	1.00029966	146.324
28	2441.087142480		19.909286963	SIO2V	1.56078570	152.142
29	-1510.264560440		88.047728958	N2VP950	1.00029966	153.326
30	-249.859723486		48.358305705	SIO2V	1.56078570	160.594
31	-214.008029106		24.481325311	N2VP950	1.00029966	169.839
32	0.000000000		0.000000000	N2VP950	1.00029966	169.727
33	0.000000000		-19.902925311	N2VP950	1.00029966	170.008
34	605.505698754		44.392798544	SIO2V	1.56078570	170.298
35	-1225.711846280	AS	0.917329000	N2VP950	1.00029966	170.093
36	268.380703332		42.756143122	SIO2V	1.56078570	162.321
37	673.253223882		0.917329000	N2VP950	1.00029966	159.910
38	227.991051127		32.036009978	SIO2V	1.56078570	146.725
39	386.401662820	AS	0.917329000	N2VP950	1.00029966	142.860
40	162.089277636		39.331357629	SIO2V	1.56078570	125.201
41	280.403904868	AS	0.261317709	N2VP950	1.00029966	119.607
42	140.568776863		116.047901278	SIO2V	1.56078570	102.577
43	0.000000000		13.799062914	H2OV	1.43636732	30.675
44	0.000000000		-0.000004642		1.00000000	14.021

Table 4

ASPHERIC CONSTANTS

SURFACE NO. 2	
K	0.0000
C1	2.19548056e-007
C2	-2.55904121e-011
C3	2.12575595e-015
C4	-2.50297943e-019
C5	3.13467504e-023
C6	-2.79504784e-027
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 15	
K	0.0000
C1	6.09055369e-009
C2	2.84395774e-013
C3	-7.49910993e-019
C4	-1.80830244e-022
C5	3.10893772e-027
C6	-2.97216228e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 4	
K	0.0000
C1	1.21102797e-008
C2	1.76786393e-011
C3	-1.87389050e-015
C4	1.72877663e-019
C5	-1.98845633e-023
C6	1.78566034e-027
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 21	
K	0.0000
C1	1.32575347e-008
C2	8.58331790e-013
C3	-1.94468414e-016
C4	-1.29822097e-020
C5	-1.77617526e-024
C6	-5.15388789e-029
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 8	
K	0.0000
C1	-9.80034077e-010
C2	2.46895064e-013
C3	4.48590254e-018
C4	-1.11608746e-022
C5	-2.09316739e-028
C6	-1.30605266e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 23	
K	0.0000
C1	-1.18145642e-008
C2	-2.83190683e-012
C3	2.26490366e-016
C4	-6.32627810e-021
C5	-1.50743622e-025
C6	8.70173390e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Table 4 (Continued)

SURFACE NO. 24	
K	0.0000
C1	-3.01246654e-008
C2	1.06355654e-012
C3	2.64650202e-017
C4	-5.31683508e-022
C5	7.81208963e-026
C6	3.39162041e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 39	
K	0.0000
C1	1.07703763e-009
C2	3.77796386e-014
C3	6.64204598e-018
C4	-2.44938953e-022
C5	6.79537323e-027
C6	-7.97331309e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 26	
K	0.0000
C1	-4.05454064e-010
C2	-9.90878824e-014
C3	-3.34054558e-018
C4	1.84085791e-022
C5	-3.65955875e-027
C6	2.72435876e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 41	
K	0.0000
C1	7.20956318e-009
C2	-4.70255323e-013
C3	4.99805454e-018
C4	3.18969937e-022
C5	-1.99338016e-026
C6	4.74226957e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 35	
K	0.0000
C1	-3.08382689e-009
C2	1.05186842e-013
C3	-1.54488832e-018
C4	2.62389724e-023
C5	-3.61488247e-028
C6	3.85542172e-033
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Table 5

SURFACE	RADII		THICKNESS	MATERIAL	INDEX	½ DIA.
0	0.000000000		32.000000000	LUFTV193	1.00030168	56.080
1	0.000000000		0.000000000	LUFTV193	1.00030168	65.155
2	-1048.799448010	AS	8.000000000	SIO2V	1.56078570	65.155
3	357.466074350		15.577785773	N2VP950	1.00029966	67.527
4	-333.124141019	AS	8.000000000	SIO2V	1.56078570	68.924
5	-6820.155766490		32.518686615	N2VP950	1.00029966	72.732
6	-108.770146111		70.263717141	SIO2V	1.56078570	74.375
7	-162.558742016		1.000000000	N2VP950	1.00029966	109.658
8	-727.250432030	AS	36.345994520	SIO2V	1.56078570	125.724
9	-234.557132237		1.000000000	N2VP950	1.00029966	128.456
10	-9857.135615630		30.073073529	SIO2V	1.56078570	135.510
11	-416.488132376		1.000000000	N2VP950	1.00029966	136.485
12	177.128692467		48.877488263	SIO2V	1.56078570	136.329
13	394.792585911		1.000000000		1.00000000	133.281
14	177.767357652		20.430936240	SIO2V	1.56078570	122.702
15	218.676264170	AS	1.000000000	N2VP950	1.00029966	118.151
16	155.471795544		47.586544113	SIO2V	1.56078570	112.186
17	242.337161267		28.571587020	N2VP950	1.00029966	98.491
18	-759.907092606	AS	8.000000000	SIO2V	1.56078570	95.650
19	102.688590330		81.578758663	N2VP950	1.00029966	76.465
20	-160.625087377		8.000000000	SIO2V	1.56078570	73.506
21	-289.596594758	AS	32.123693558	N2VP950	1.00029966	75.482
22	-94.386389420		8.000000000	SIO2V	1.56078570	75.641
23	393.984728152	AS	43.431984001	N2VP950	1.00029966	100.441
24	-383.629532182	AS	48.428600019	SIO2V	1.56078570	115.392
25	-159.278903132		1.000000000	N2VP950	1.00029966	123.564
26	-1493.341508910	AS	41.723752694	SIO2V	1.56078570	155.895
27	-311.773166805		1.000000000	N2VP950	1.00029966	159.465
28	790.204177656		64.210221574	SIO2V	1.56078570	183.877
29	-513.494438444		48.508920065	N2VP950	1.00029966	184.913
30	0.000000000		0.000000000	N2VP950	1.00029966	183.970
31	0.000000000		-4.679353550	N2VP950	1.00029966	184.111
32	1228.823190020		99.991561318	SIO2V	1.56078570	184.706
33	-727.663147183	AS	1.000000000	N2VP950	1.00029966	184.894
34	543.534872302		45.268294559	SIO2V	1.56078570	178.330
35	-2190.264622390		1.000000000	N2VP950	1.00029966	176.712
36	321.195671013		38.692254682	SIO2V	1.56078570	157.822
37	1247.251021990	AS	1.000000000	N2VP950	1.00029966	154.258
38	152.057533078		64.095023650	SIO2V	1.56078570	121.939
39	242.847796060	AS	-0.663115549	N2VP950	1.00029966	102.223
40	159.282474016	AS	100.471918401	SIO2V	1.56078570	92.400
41	0.000000000		6.000000000	H2OV	1.43636732	21.211
42	0.000000000		-0.000005061		1.00000000	14.020

Table 6

ASPHERIC CONSTANTS

SURFACE NO. 2	
K	0.0000
C1	1.68161638e-007
C2	-1.54096885e-011
C3	6.84912375e-016
C4	-1.65634098e-020
C5	-4.21003140e-024
C6	-3.70097554e-029
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 15	
K	0.0000
C1	6.90734885e-009
C2	3.24772979e-013
C3	-4.32878458e-018
C4	8.45718239e-023
C5	-7.59398340e-027
C6	-8.33908359e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 4	
K	0.0000
C1	4.16802658e-008
C2	7.71901817e-012
C3	-4.85374566e-016
C4	2.38634680e-020
C5	-4.52727128e-024
C6	7.55327461e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 18	
K	0.0000
C1	2.57656877e-008
C2	-5.66778843e-013
C3	1.33836752e-017
C4	1.55594835e-021
C5	-2.95962449e-026
C6	8.80071238e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 8	
K	0.0000
C1	-1.03251955e-009
C2	3.10271087e-013
C3	9.94527633e-019
C4	-1.95266425e-024
C5	-1.31835831e-027
C6	-8.30589618e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 21	
K	0.0000
C1	3.59827387e-008
C2	-1.04290688e-012
C3	-2.20602889e-016
C4	-6.36815229e-021
C5	-1.16915922e-024
C6	9.91429003e-029
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Table 6 (Continued)

SURFACE NO. 23	
K	0.0000
C1	-2.10673727e-008
C2	-3.25666446e-013
C3	8.28426536e-017
C4	-5.44862524e-021
C5	1.92784030e-025
C6	-2.98813211e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 33	
K	0.0000
C1	-3.95098549e-010
C2	6.14454866e-014
C3	-8.49150328e-019
C4	1.23852443e-023
C5	-1.40221953e-028
C6	1.12769246e-033
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 24	
K	0.0000
C1	-1.96101498e-008
C2	5.26331679e-013
C3	-7.77887850e-018
C4	-8.47002846e-023
C5	8.55175584e-027
C6	8.94134535e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 37	
K	0.0000
C1	-6.81965171e-010
C2	1.52609195e-013
C3	-2.77686953e-018
C4	7.44204272e-023
C5	-1.04495599e-027
C6	1.09377342e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 26	
K	0.0000
C1	-3.49919825e-009
C2	-1.30490066e-014
C3	-5.06174090e-019
C4	9.13296563e-023
C5	-2.55183113e-027
C6	3.40427662e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 39	
K	0.0000
C1	-1.36259017e-008
C2	-5.89574710e-013
C3	4.45586739e-017
C4	-3.23689763e-021
C5	1.35843971e-025
C6	-2.48308030e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Table 6 (Continued)

SURFACE NO. 40	
K	0.0000
C1	3.65468233e-009
C2	-4.30642726e-013
C3	-2.68984250e-017
C4	-3.34659737e-021
C5	-8.98569869e-026
C6	-7.82863465e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Table 7

SURFACE	RADII		THICKNESS	MATERIAL	INDEX	½ DIA.
0	0.000000000		32.000000000	LUFTV193	1.00030168	56.080
1	0.000000000		0.000000000	LUFTV193	1.00030168	65.489
2	-1062.644333890	AS	7.338632000	SIO2V	1.56078570	65.489
3	255.022949911		16.160579368	N2VP950	1.00029966	68.355
4	-489.014433512	AS	7.338632000	SIO2V	1.56078570	69.941
5	-953.561289631		30.032974919	N2VP950	1.00029966	72.518
6	-107.396495083		74.650939249	SIO2V	1.56078570	74.020
7	-161.142164897		0.917329000	N2VP950	1.00029966	111.131
8	-488.188913438	AS	30.492609399	SIO2V	1.56078570	125.220
9	-232.490185472		0.917329000	N2VP950	1.00029966	127.932
10	1343.823788180		38.249501740	SIO2V	1.56078570	138.358
11	-419.035035978		0.917329000	N2VP950	1.00029966	139.112
12	306.451436457		35.457384811	SIO2V	1.56078570	137.109
13	2158.254218050		0.917329000		1.00000000	135.666
14	159.158336522		32.442139208	SIO2V	1.56078570	121.180
15	127.737640923	AS	4.348966155	N2VP950	1.00029966	104.078
16	118.494774202		54.712473071	SIO2V	1.56078570	102.621
17	412.552433435		16.035419865	N2VP950	1.00029966	98.302
18	-4861.779621850		7.338632000	SIO2V	1.56078570	95.571
19	91.974383893		43.651541247	N2VP950	1.00029966	74.779
20	327.075494024		7.338632000	SIO2V	1.56078570	74.236
21	135.224109914	AS	61.165891668	N2VP950	1.00029966	72.300
22	-94.564006353		7.338632000	SIO2V	1.56078570	73.152
23	443.040353676	AS	31.146857264	N2VP950	1.00029966	95.986
24	-279.871691536	AS	60.693055925	SIO2V	1.56078570	99.666
25	-136.823756204		0.917329000	N2VP950	1.00029966	114.157
26	704.411514093	AS	35.987586734	SIO2V	1.56078570	154.664
27	-948.888201521		0.917329000	N2VP950	1.00029966	156.351
28	559.811238443		31.625999039	SIO2V	1.56078570	166.779
29	12181.115095000		0.917329000	N2VP950	1.00029966	167.117
30	380.238637765		27.195202255	SIO2V	1.56078570	170.304
31	343.392987049		92.899538604	N2VP950	1.00029966	166.494
32	-322.169569503		29.169280971	SIO2V	1.56078570	166.857
33	-260.838847150		9.648793391	N2VP950	1.00029966	170.326
34	0.000000000		0.000000000	N2VP950	1.00029966	169.266
35	0.000000000		-5.070393391	N2VP950	1.00029966	169.539
36	1144.263596070		39.257312498	SIO2V	1.56078570	170.163
37	-798.249268006	AS	0.917329000	N2VP950	1.00029966	170.326
38	229.347879309		46.353683772	SIO2V	1.56078570	162.434
39	462.344917067		0.917329000	N2VP950	1.00029966	159.641
40	211.811588624		34.925776908	SIO2V	1.56078570	147.256
41	350.839735917	AS	0.921675011	N2VP950	1.00029966	143.083
42	165.268731319		38.136683982	SIO2V	1.56078570	126.377
43	299.200544748	AS	0.875756502	N2VP950	1.00029966	120.636
44	137.008198061		116.675902093	SIO2V	1.56078570	102.388
45	0.000000000		13.114474182	H2OV	1.43636732	30.176
46	0.000000000		-0.000004642		1.00000000	14.020

Table 8

ASPHERIC CONSTANTS

SURFACE NO. 2	
K	0.0000
C1	1.68614396e-007
C2	-1.62938343e-011
C3	1.05824627e-015
C4	-1.37635154e-019
C5	1.19544176e-023
C6	-1.08466996e-027
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 15	
K	0.0000
C1	4.38226999e-009
C2	3.29996569e-013
C3	1.05160037e-017
C4	1.87360439e-021
C5	-9.58603937e-026
C6	9.89801169e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 4	
K	0.0000
C1	2.66602257e-008
C2	8.08770917e-012
C3	-5.17405228e-016
C4	5.24648371e-020
C5	-5.31079981e-024
C6	7.03891423e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 21	
K	0.0000
C1	-5.05562903e-008
C2	-1.71111261e-012
C3	-2.39846224e-016
C4	-9.56041789e-021
C5	-2.55077988e-024
C6	1.19373744e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 8	
K	0.0000
C1	5.53338685e-010
C2	1.96957668e-013
C3	3.33693370e-018
C4	8.08706552e-023
C5	-4.53301354e-027
C6	5.92857180e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 23	
K	0.0000
C1	-9.36460326e-009
C2	-1.95070287e-012
C3	1.26771856e-016
C4	-1.61670698e-021
C5	-1.70527743e-025
C6	4.82096354e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Table 8 (Continued)

SURFACE NO. 24	
K	0.0000
C1	-1.57685441e-008
C2	7.13669735e-013
C3	1.19267788e-017
C4	1.05805275e-021
C5	-5.62569676e-026
C6	4.37929930e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 41	
K	0.0000
C1	7.57307476e-010
C2	9.35948303e-014
C3	2.83877521e-018
C4	-3.88341724e-023
C5	-4.69204092e-028
C6	2.40453633e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 26	
K	0.0000
C1	-9.64817190e-010
C2	-9.31263573e-014
C3	8.41272007e-019
C4	1.13509448e-023
C5	-3.23524042e-028
C6	2.54061862e-034
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 43	
K	0.0000
C1	1.65656760e-008
C2	-3.94462332e-013
C3	5.26534821e-018
C4	8.11693181e-023
C5	8.51261908e-028
C6	-8.63707035e-033
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. . 37	
K	0.0000
C1	-2.58804293e-009
C2	5.52462737e-014
C3	1.45362116e-019
C4	-8.27631859e-024
C5	1.95716231e-028
C6	-1.15654876e-033
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Table 9

SURFACE	RADII		THICKNESS	MATERIAL	INDEX	½ DIA.
0	0.000000000		9.142005173	LUFTV193	1.00030168	56.080
1	0.000000000		0.000000000	LUFTV193	1.00030168	58.731
2	-1470.436757260	AS	13.765312317	SIO2V	1.56078570	58.731
3	-3309.611646770		13.689116258	N2VP950	1.00029966	60.942
4	-153.660957229	AS	16.198295814	SIO2V	1.56078570	61.761
5	-1763.435772780		31.442460406	N2VP950	1.00029966	69.003
6	-101.844101742		76.042936327	SIO2V	1.56078570	70.803
7	-163.782835464		0.917378575	N2VP950	1.00029966	108.830
8	-1459.635075060	AS	54.159718049	SIO2V	1.56078570	125.867
9	-248.697896110		4.472798922	N2VP950	1.00029966	132.539
10	560.790862895		42.185267856	SIO2V	1.56078570	141.601
11	-609.964403728		0.918264301	N2VP950	1.00029966	141.592
12	198.271861860		27.448715534	SIO2V	1.56078570	132.123
13	290.843457645		0.917329000		1.00000000	129.324
14	188.555316943		20.510844557	SIO2V	1.56078570	123.887
15	247.160314957	AS	0.917329000	N2VP950	1.00029966	120.246
16	155.775852649		47.187992124	SIO2V	1.56078570	113.216
17	664.453413397		13.812670100	N2VP950	1.00029966	108.654
18	-3356.640701870		8.416525213	SIO2V	1.56078570	105.334
19	90.376617717	AS	54.983687982	N2VP950	1.00029966	78.772
20	415.881397199		24.694228340	SIO2V	1.56078570	76.825
21	136.348844236	AS	53.170614917	N2VP950	1.00029966	71.868
22	-101.270354507		7.338632000	SIO2V	1.56078570	72.201
23	315.798684812	AS	30.568540809	N2VP950	1.00029966	91.548
24	-323.927336065	AS	57.126593193	SIO2V	1.56078570	95.152
25	-134.032849637		0.917337523	N2VP950	1.00029966	108.301
26	774.857052737	AS	32.455181674	SIO2V	1.56078570	142.537
27	-796.651828605		0.917486275	N2VP950	1.00029966	144.320
28	2090.903995650		19.600542254	SIO2V	1.56078570	149.676
29	-1654.430592690		106.639451642	N2VP950	1.00029966	150.742
30	-251.588121950		48.355102294	SIO2V	1.56078570	160.496
31	-218.239336745		26.904051486	N2VP950	1.00029966	170.054
32	0.000000000		0.000000000	N2VP950	1.00029966	169.725
33	0.000000000		-22.325651487	N2VP950	1.00029966	170.012
34	553.234026434		47.365023716	SIO2V	1.56078570	170.296
35	-1166.719282260	AS	0.917329000	N2VP950	1.00029966	170.011
36	251.636939637		38.983925925	SIO2V	1.56078570	160.302
37	490.044240843		0.917329000	N2VP950	1.00029966	157.650
38	225.522557608		32.229047503	SIO2V	1.56078570	146.808
39	379.561748132	AS	0.917329000	N2VP950	1.00029966	142.928
40	161.928081339		40.681093415	SIO2V	1.56078570	125.478
41	296.179623509	AS	0.264406882	N2VP950	1.00029966	119.880
42	142.195492897		115.800030845	SIO2V	1.56078570	102.493
43	0.000000000		13.207879330	H2OV	1.43636732	29.971
44	0.000000000		-0.000004642		1.00000000	14.020

Table 10

ASPHERIC CONSTANTS

SURFACE NO. 2	
K	0.0000
C1	1.12469050e-007
C2	-3.50824385e-012
C3	-2.74862507e-016
C4	-9.33617181e-020
C5	4.62214912e-023
C6	-2.44278252e-027
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 15	
K	0.0000
C1	6.99382393e-009
C2	2.94148363e-013
C3	-9.11800329e-018
C4	1.91618690e-022
C5	-4.40019705e-027
C6	-1.08562596e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 4	
K	0.0000
C1	1.40101009e-007
C2	-9.52563322e-013
C3	3.75239564e-017
C4	-7.55582902e-020
C5	6.00534431e-024
C6	-2.68655709e-027
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 19	
K	-0.1408
C1	0.00000000e+000
C2	0.00000000e+000
C3	0.00000000e+000
C4	0.00000000e+000
C5	0.00000000e+000
C6	0.00000000e+000
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 8	
K	0.0000
C1	-7.38527199e-009
C2	6.03324901e-013
C3	-1.60270644e-017
C4	4.33148931e-022
C5	-8.09105093e-027
C6	4.84794945e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 21	
K	0.0000
C1	-1.89926056e-008
C2	-9.48909538e-013
C3	-1.00991502e-016
C4	-1.76312640e-020
C5	-3.18703391e-025
C6	-2.53640530e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Table 10 (Continued)

SURFACE NO. 23	
K	0.0000
C1	-1.45577789e-008
C2	-1.93419367e-012
C3	8.86661418e-017
C4	4.86248409e-021
C5	-5.62562318e-025
C6	1.49006191e-029
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 35	
K	0.0000
C1	-3.09623921e-009
C2	1.10211887e-013
C3	-1.63603595e-018
C4	2.33267959e-023
C5	-1.93983389e-028
C6	1.41288956e-033
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 24	
K	0.0000
C1	-2.59671120e-008
C2	1.04865633e-012
C3	2.30233796e-017
C4	4.93824742e-022
C5	-2.54396468e-026
C6	3.57571325e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 39	
K	0.0000
C1	1.45949460e-009
C2	1.84182220e-014
C3	7.21345576e-018
C4	-2.08810169e-022
C5	4.09729831e-027
C6	-4.05213812e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 26	
K	0.0000
C1	-3.10596549e-010
C2	-1.27212114e-013
C3	-2.15526174e-018
C4	1.18522610e-022
C5	-2.43335508e-027
C6	6.68951355e-033
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 41	
K	0.0000
C1	1.08716684e-008
C2	-5.59272513e-013
C3	7.30283609e-018
C4	-1.55126694e-023
C5	3.59751728e-027
C6	-4.37399769e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Table 11

SURFACE	RADII		THICKNESS	MATERIAL	INDEX	½ DIA.
0	0.000000000		31.931002664		1.00000000	56.080
1	-347.236440528	AS	8.000000000	SIO2HL	1.56028890	66.189
2	219.915562477		31.898415726	N2VP950	1.00000300	70.391
3	-170.858136470		8.000000000	SIO2HL	1.56028890	72.892
4	1107.474957290	AS	22.589356201	N2VP950	1.00000300	89.106
5	-218.108339374	AS	63.099650288	SIO2HL	1.56028890	93.885
6	-135.240822500		1.000000000	N2VP950	1.00000300	109.625
7	32003.375547500		47.413691277	SIO2HL	1.56028890	137.108
8	-282.465638980		1.000000000	N2VP950	1.00000300	139.973
9	297.920255954		48.926206712	SIO2HL	1.56028890	151.093
10	-1765.218425420	AS	1.000000000	N2VP950	1.00000300	149.869
11	155.350309269		62.064795636	SIO2HL	1.56028890	138.044
12	287.967685928		1.000000000	N2VP950	1.00000300	131.984
13	197.466973091		46.435923957	SIO2HL	1.56028890	123.714
14	155.967795233	AS	1.000000000	N2VP950	1.00000300	102.169
15	175.615580039		8.000000000	SIO2HL	1.56028890	98.890
16	81.433239279		58.962282942	N2VP950	1.00000300	76.029
17	-1042.836597030		8.000000000	SIO2HL	1.56028890	75.001
18	236.916783020	AS	57.069488559	N2VP950	1.00000300	72.144
19	-81.739367888		8.000000000	SIO2HL	1.56028890	71.687
20	375.086948338	AS	30.278553523	N2VP950	1.00000300	99.714
21	-342.008757539		57.142725147	SIO2HL	1.56028890	104.436
22	-160.258782239		1.000000000	N2VP950	1.00000300	119.685
23	-856.839164376	AS	34.689165048	SIO2HL	1.56028890	148.650
24	-379.653604267		1.000000000	N2VP950	1.00000300	152.636
25	584.985383859	AS	45.511042875	SIO2HL	1.56028890	172.438
26	-958.601764530		1.000000000	N2VP950	1.00000300	174.054
27	666.780520883	AS	50.027876765	SIO2HL	1.56028890	180.001
28	-963.390274276		-11.963951541	N2VP950	1.00000300	179.996
29	0.000000000		29.192598777	N2VP950	1.00000300	179.451
30	278.073032381		42.845705807	SIO2HL	1.56028890	179.994
31	488.477056296		1.000000000	N2VP950	1.00000300	177.191
32	229.130061526		59.928766081	SIO2HL	1.56028890	168.083
33	493.528859065	AS	1.000000000	N2VP950	1.00000300	163.249
34	168.416619548		45.625591423	SIO2HL	1.56028890	134.017
35	311.455238476	AS	1.000000000	N2VP950	1.00000300	125.436
36	111.636678699		48.342194715	SIO2HL	1.56028890	97.724
37	210.829981018	AS	1.000000000	N2VP950	1.00000300	81.689
38	124.000721148		73.536543337	SIO2HL	1.56028890	75.223
39	0.000000000		1.737330768	IMMERS	1.43500000	16.708
40	0.000000000		0.000000000		1.00000000	14.020

Table 12

ASPHERIC CONSTANTS

SURFACE NO. 1	
K	0.0000
C1	3.43015837e-007
C2	-4.07245548e-011
C3	5.68690697e-015
C4	-9.66005925e-019
C5	1.80932906e-022
C6	-2.31865517e-026
C7	1.32319202e-030
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 10	
K	0.0000
C1	3.14962178e-008
C2	-1.06476758e-012
C3	3.51750146e-017
C4	-1.39021700e-021
C5	5.08855180e-026
C6	-1.41732059e-030
C7	2.05140486e-035
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 4	
K	0.0000
C1	1.45742246e-007
C2	-2.96891550e-011
C3	2.11941800e-015
C4	1.87281593e-021
C5	-1.70520532e-023
C6	1.41301018e-027
C7	-4.45795966e-032
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 14	
K	0.0000
C1	-1.80801250e-007
C2	1.03835381e-011
C3	-1.22571643e-016
C4	-4.12834819e-021
C5	-2.33128210e-024
C6	3.14464121e-028
C7	-1.42364051e-032
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 5	
K	0.0000
C1	1.14210231e-007
C2	-2.56390958e-012
C3	6.23158150e-017
C4	-1.54942908e-020
C5	2.11301267e-024
C6	-1.87409843e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 18	
K	0.0000
C1	4.71514493e-008
C2	-4.46566204e-012
C3	-1.36375356e-015
C4	3.64942050e-020
C5	-3.50695421e-023
C6	6.42482495e-027
C7	-7.49653419e-031
C8	0.00000000e+000
C9	0.00000000e+000

Table 12 (Continued)

SURFACE NO. 20	
K	0.0000
C1	-1.99816626e-008
C2	-6.60214059e-012
C3	1.10140693e-015
C4	-1.05954816e-019
C5	6.81490959e-024
C6	-2.72419422e-028
C7	4.97767443e-033
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 23	
K	0.0000
C1	1.74400115e-008
C2	-8.35191566e-014
C3	-6.72245819e-018
C4	-1.48911061e-022
C5	6.03163011e-027
C6	-7.22356694e-032
C7	-1.68350772e-036
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 25	
K	0.0000
C1	-6.26229360e-009
C2	-1.01689566e-013
C3	1.24265213e-018
C4	6.15676137e-023
C5	-1.81952531e-027
C6	7.05339612e-032
C7	-1.30796023e-036
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 27	
K	0.0000
C1	-3.11584500e-009
C2	4.54152967e-014
C3	5.48854826e-019
C4	-1.07217364e-023
C5	-4.93680366e-028
C6	4.40409387e-033
C7	1.80136796e-037
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 33	
K	0.0000
C1	2.03860365e-009
C2	-4.81770739e-013
C3	7.12906529e-018
C4	-9.89082418e-023
C5	5.97992904e-027
C6	-1.39296989e-031
C7	1.16280644e-036
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO. 35	
K	0.0000
C1	1.36126851e-008
C2	-2.50085436e-013
C3	1.07338114e-018
C4	3.24701476e-021
C5	-1.00209509e-025
C6	-2.59101058e-031
C7	1.08664414e-034
C8	0.00000000e+000
C9	0.00000000e+000

Table 12 (Continued)

SURFACE NO. 37	
K	0.0000
C1	8.99963419e-008
C2	6.04018944e-012
C3	-7.89329450e-017
C4	-2.13781701e-021
C5	6.69330154e-024
C6	-7.04221608e-028
C7	4.04933330e-032
C8	0.00000000e+000
C9	0.00000000e+000